Space Technology Research Grants

Hierarchical Composites with Nanostructured Reinforcement for Multifunctional Aerospace Structures

Completed Technology Project (2014 - 2018)

Project Introduction

Advanced nano-engineered composites hold great potential for augmenting aerospace composites material performance by reducing spacecraft weight, increasing payload capacity, and offering flexibility in mission profiles. In particular, radially grown carbon nanotubes (CNTs) on microfibers formulate a 'fuzzy fiber' reinforced plastic (FFRP) architecture that has been both analytically and empirically shown to improve weak interlaminar properties of composites such as mode I fracture toughness and interlaminar shear strength. Additionally, lightweight multifunctional attributes can be integrated into the composite through the electrically and thermally conductive network of CNTs. While this architecture has been demonstrated on alumina fiber composites, the implementation of fuzzy carbon fiber reinforced plastics (fuzzy CFRP) desired for lightweight high-performing aerospace structures -- has been elusive. High-yield CNT growth on carbon fibers (CF) has required detrimental surface modifications/acid etching and high-temperature thermal Chemical Vapor Deposition (CVD) processes, which incur up to 60% loss of fiber tensile strength and diminish in-plane mechanical performance of the resultant CNT-hybridized carbon fiber composites. We present an innovative method for high-yield growth of CNTs on CF without degrading microfiber tensile properties by employing two strategies: non-covalent functionalization of the CF surface for catalyst adhesion, and low-temperature CVD processing. The scalability of our simple dip-coating technique and more efficient CNT growth is demonstrated by my recent work in successfully manufacturing unidirectional fuzzy CFRP specimens. Tensile testing of these hierarchical composites has shown preservation of longitudinal modulus and strength, thus avoiding the compromise of in-plane characteristics, and paving the way for fuzzy CFRP with all-around enhanced mechanical properties. More recently, I have successfully begun to expand fabrication to larger laminate-level fuzzy CFRP samples by growing CNT on aerospace carbon fiber weaves. In this proposed study, I will focus on manufacturing laminate specimens to determine the efficacy of fuzzy CFRP in improving damage tolerance and impact resistance crucial for advancing micrometeoroid and orbital debris (MMOD) impact shielding for spacecraft, and assembly/transport related damage protection for launch vehicles. Characterizations of ballistic toughness for fuzzy CFRP at different impact energy levels will be performed at the NASA Glenn Research Center's Ballistic Testing Facility. Compression after impact and open-hole tension/compression tests will also be performed to evaluate damage tolerance improvements. Electrical conductivities of laminate specimens will also be characterized to determine feasibility in lightweight multifunctional applications of fuzzy CFRP for integrated electronic wiring and lightning strike protection. Lastly, understanding gained from impact damage analyses and conductivity measurements will be merged to investigate the efficacy of nano-engineered thermal non-destructive evaluation (NET-NDE) for in situ low-power damage detection (including barely visible impact damage), as was effectively demonstrated for alumina FFRPs. Through collaboration with NASA Glenn, this study will aim towards developing a truly multifunctional,

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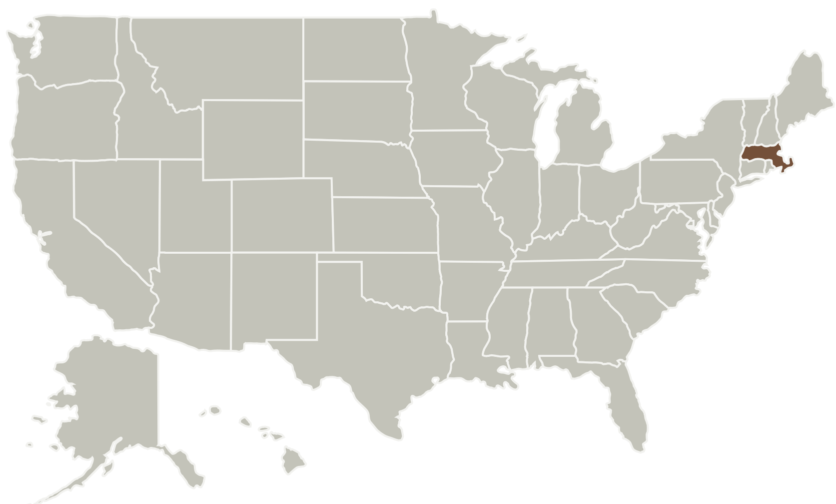
damage tolerant, and damage resistant hierarchical composite material to meet NASA Space Technology Mission Directorate goals.

Anticipated Benefits

Through collaboration with NASA Glenn, this study will aim towards developing a truly multifunctional, damage tolerant, and damage resistant hierarchical composite material to meet NASA Space Technology Mission Directorate goals. Advanced nano-engineered composites hold great potential for augmenting aerospace composites material performance by reducing spacecraft weight, increasing payload capacity, and offering flexibility in mission profiles.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Massachusetts Institute of Technology(MIT)	Lead Organization	Academia	Cambridge, Massachusetts

Primary U.S. Work Locations
Massachusetts

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Massachusetts Institute of Technology (MIT)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

Brian Wardle

Co-Investigator:

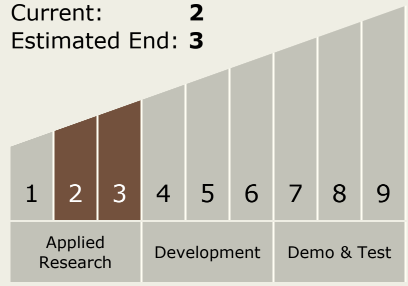
Richard K Li

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX13 Ground, Test, and Surface Systems
  - └ TX13.1 Infrastructure Optimization
    - └ TX13.1.7 Impact/Damage/Radiation Resistant Systems

Target Destination

Earth